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The Impact of Industrial Sites on Residential Property Values: A Hedonic Pricing Analysis from the Netherlands

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The Impact of Industrial Sites on Residential Property Values: A Hedonic Pricing Analysis from the Netherlands

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DE VOR F. and DE GROOT H. L. F. The impact of industrial sites on residential property values: a hedonic pricing analysis from the Netherlands, *Regional Studies*. Industrial sites cause several negative externalities. In order to quantify these negative effects, the impact of distance to industrial sites on residential property values is estimated. Data on houses sold in the Randstad region and in the Province of North-Brabant (both located in the Netherlands) in the year 2005 are used, together with data on the characteristics of industrial sites in the same regions and period. The distance to an industrial site exhibits a statistically significant negative effect on the value of residential properties. However, the effect is largely localized within a relatively short distance from the nearest industrial site.

Industrial sites Negative externalities Hedonic pricing

DE VOR F. and DE GROOT H. L. F. 产业用地对于居住地产价值的影响：享乐定价法分析，荷兰，区域研究。产业用地引发了诸多负面效应。为了量化上述负面影响，笔者估测了产业用地对居住地产的影响。本研究采纳了2005年任仕达（Randstad）地区及北布拉班特省的房屋销售数据，以及同时期、同区域中反映产业用地特征的数据。上述数据表明，产业与居住用地之间的距离对居住地产的价值产生了负面影响，然而这种影响仅出现在距产业区较短距离的居住地产中。

产业用地 消极外部性 享乐定价法

DE VOR F. et DE GROOT H. L. F. L'impact des sites industriels sur la valeur des logements: une analyse néerlandaise de la détermination hédonique des prix, *Regional Studies*. Les sites industriels ont plusieurs effets externes négatifs. Pour quantifier ces effets négatifs, on estime l'impact de la distance aux sites industriels sur la valeur des logements. On emploie des données sur les logements vendus dans la région Randstad et dans la province de Brabant du Nord (les deux étant situées en Hollande) pour l'année 2005, conjointement avec des données sur les caractéristiques des sites industriels situés dans les mêmes régions à la même époque. Il s'avère que la distance à un site industriel a un effet négatif statistiquement important sur la valeur des logements. Toujours est-il que l'effet est dans une large mesure restreint à une distance relativement courte du site industriel le plus proche.

Sites industriels Effets externes négatifs Détermination hédonique des prix

DE VOR F. und DE GROOT H. L. F. Auswirkung von Industriestandorten auf den Wert von Wohnimmobilien: eine hedonische Preisanalyse in den Niederlanden, *Regional Studies*. Industriestandorte verursachen mehrere negative Externalitäten. Zur Quantifizierung dieser negativen Effekte wird die Auswirkung der Entfernung von Industriestandorten auf den Wert von Wohnimmobilien geschätzt. Hierfür kommen die Daten von Häusern zum Einsatz, die im Jahr 2005 in der Randstad-Region sowie in der Provinz Nordbrabant (beide in den Niederlanden) verkauft wurden, sowie die Daten über die Merkmale von Industriestandorten in denselben Regionen und im selben Zeitraum. Die Entfernung von einem Industriestandort wirkt sich auf statistisch signifikante Weise negativ auf den Wert von Wohnimmobilien aus. Allerdings ist diese Auswirkung größtenteils auf eine relativ kurze Entfernung bis zum nächsten Industriestandort begrenzt.

Industriestandorte Negative Externalitäten Hedonische Preiskalkulation

DE VOR F. y DE GROOT H. L. F. El efecto de los polígonos industriales en los valores de bienes inmuebles residenciales: análisis de precios hedónicos en los Países Bajos, *Regional Studies*. Los polígonos industriales causan varios efectos externos negativos. A fin de cuantificar estos efectos negativos, calculamos el impacto de la distancia a los polígonos industriales en los valores de bienes

inmuebles residenciales. Utilizamos datos de viviendas vendidas en la región de Randstad y la provincia de Brabante Septentrional (ambas en los Países Bajos) en el año 2005, junto con datos sobre las características de los polígonos industriales en los mismos periodos y regiones. La distancia a un polígono industrial muestra un efecto negativo estadísticamente significativo sobre el valor de los bienes inmuebles residenciales. Sin embargo, el efecto está en gran medida localizado dentro de una distancia relativamente corta desde el polígono industrial más cercano.

Polígonos industriales Efectos externos negativos Precios hedónicos

JEL classifications: O18, R30, R52

INTRODUCTION

The results of Dutch policies aimed at providing an adequate supply of industrial land are mixed. In accordance with the spatial policy objectives, industrial sites have become the main location for supplying industrial land. Slowly but steadily, both the amount and the share of employment on industrial sites are rising. Industrial sites are now a favourable place to settle for many firms (LOUW and BONTEKONING, 2007), and can be considered important contributors to the (local) economy: such sites occupy about 2% of the total area of the Netherlands, and account for about one-third of the national output (LOUW *et al.*, 2007). However, the recent planning debates about Dutch industrial sites have focused strongly on the quality of industrial sites (LOUW *et al.*, 2004). Concerns have been raised about the possible negative external effects of industrial activities on other firms, on nature, and particularly on households (SCHUUR, 2001; NEEDHAM and LOUW, 2003; LOUW *et al.*, 2004; BLAAUW, 2007). Although the development of industrial sites in the Netherlands is based on the mono-functional policy concept of separating industry and housing, residents may still be affected by industrial sites because of a multitude of perceived disamenities, such as noise, traffic, congestion, air pollution, and obstruction of view.

This study contributes to the planning debate by elaborating on the implications of the presence of industrial sites on their immediate vicinity, distinguishing between various types of industrial sites.¹ It aims to measure the negative externalities generated by industrial sites, and to obtain insight into the scope of these externalities. By means of a hedonic pricing analysis of residential property transactions, the impact – *ceteris paribus* – of the distance to industrial sites on property transaction prices is identified. Furthermore, the implications of the characteristics of an industrial site on the magnitude of its impact are examined by differentiating according to the size of the industrial site concerned. Many existing studies dealing with the topic of negative externalities generated by industrial sites consider a specific, tightly framed, study area comprising a restricted number of industrial sites. These studies arrive at a multitude of outcomes referring to a variety of specific cases.² In this respect, the present study deviates from this literature by employing a

more general approach: it analyses a comprehensive sample of industrial sites and identifies the effects of these sites on neighbouring house prices in the Randstad region and in the Province of North-Brabant (both in the Netherlands).

The paper is organized as follows. It starts with a discussion of the literature on negative externalities originating from industrial facilities and hedonic pricing. The Dutch (policy) context with regard to the negative external effects of industrial sites is subsequently reviewed. It then continues with a presentation of the characteristics of the data set underlying the analysis and the research set-up, followed by a discussion of the econometric model and the estimation results. The paper concludes with a summary and discussion of policy implications.

LITERATURE REVIEW

FARBER (1998) provides a survey of the literature on the impact of undesirable facilities on house values due to perceived disamenities. Such concerns range from worries about health risks to those about the public image of the community. They can manifest themselves in property markets, since it is most likely that people are willing to pay more to reside in locations further located from perceived disamenities. The survey confirms that undesirable facilities (for example, landfills, waste sites, hazardous manufacturing facilities) reduce property values in their immediate vicinity. These adverse effects diminish with distance, resulting in increased property values as distance from these sites increases. Moreover, these adverse property value effects appear to be relatively localized. Other examples can be found in a number of studies which have shown effects on property values caused by proximity to a contaminated site. These studies (for example, SMOLEN *et al.*, 1991; and MENDELSON *et al.*, 1992) have reported adverse impacts on values, ranging from as low as 0.24% to as high as 25%, depending on the extent of pollution and the location of the property. In view of the Dutch situation, VISSER and VAN DAM (2006) have analysed the housing market in the Netherlands as a whole and have focused on, among other things, the contribution of environmental characteristics to house price variation. By taking into account

various characteristics within the immediate vicinity (50 metres) of the dwelling concerned (for example, the presence of parks, open space, and industrial land, the nature and quality of buildings, the social status of the neighbourhood, distance to services, and infrastructure), they conclude that property value is positively affected by the quality of its vicinity in terms of the availability of amenities. For instance, houses located in low-density, leafy neighbourhoods are valued significantly higher than houses in high-density areas with a lack of parks and open space. Conversely, disamenities, such as the presence of industrial land and proximity to a highway, affect the prices negatively. These findings suggest that effects generated by (dis)amenities operate especially on a local scale, which confirms the notion that impact decreases with distance. These outcomes are confirmed by the more detailed studies concerning the Dutch situation of ROUWENDAL and VAN DER STRAATEN (2008), DEKKERS and VAN DER STRAATEN (2008), and DEBREZION *et al.* (2006). The first of these studies shows that, in three major Dutch cities (Amsterdam, Rotterdam, and The Hague), parks and public gardens within the immediate vicinity of houses increase their value. Considering the three investigated cities, the city of Amsterdam has the highest price per square metre of floor area, which is in line with the tight housing market situation in Amsterdam and the fact that the average floor area is the smallest in Amsterdam. However, the willingness to pay for open space appears to be lowest in Amsterdam. This finding is caused by the relatively low average quality of the different parks and public gardens in Amsterdam, compared with those in Rotterdam and The Hague. It shows that, as well as vicinity, the quality of the amenity matters. The second study investigates the effect of aircraft noise on house prices in the highly urbanized area around Amsterdam Schiphol Airport. Controlling for multiple sources of traffic noise, air traffic yields the largest price impact, followed by railway traffic, and road traffic. Finally, the third study analyses the effect of the accessibility provided by Dutch railway stations on residential house prices. It shows that house prices decrease with distance from a railway station, revealing the positive effect of proximity. This effect is enhanced by the increased frequency of train services at a station. Hence, these three studies provide insights into the efficiency of public policy in terms of optimal open space provision, aircraft noise reduction measures, and railway station accessibility, respectively.

As the existing literature has mainly focused on cataloguing the adverse effects on property values, less is known about the magnitude with which the property values may increase following a clean-up or regeneration of a site. Exceptions are DALE *et al.* (1999) and MCCOMB (2004), who report that property values around the sites under investigation appeared to be lower before the clean-up or regeneration. However, after the clean-up, the prices consistently rebounded,

although in the areas closest to the site and the poorest neighbourhoods prices rebounded more slowly. These studies underline that taking into account specific properties of sites may increase the accurateness of predicting the impact effects.

The previously mentioned studies are useful to demonstrate the nature and intensity of the impact of local forms of land use. Generally, they are based on revealed preference methods to observe what individuals really pay or require in compensation for living in the vicinity of sites that generate negative externalities (FARBER, 1998). Hedonic pricing methods are helpful to identify the impact of the various externalities (ROSEN, 1974). Hedonic prices are defined as the implicit prices of attributes, which are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them. More specifically, in hedonic price analysis, house prices are regressed on a vector of inherent attributes. A hedonic equation helps to explain house prices in terms of the house's own characteristics, such as the type of dwelling, age, floor area, neighbourhood characteristics, and job accessibility. Each of these attributes is assumed to be implicitly priced. The real-estate literature is replete with hedonic pricing models estimating the willingness to pay for housing characteristics (for example, LINNEMAN, 1981; and PALMQUIST, 2005). In addition, there has been a growing literature that uses the hedonic pricing model to measure the impact of environmental amenities and disamenities on real-estate values (for example, KOHLHASE, 1991, HITE *et al.*, 2001, KIEL and ZABEL, 2001; and KAUFMAN and CLOUTIER, 2006).

However, hedonic pricing methods have some limitations (FARBER, 1998; KIEL and ZABEL, 2001). First, property markets may not be in equilibrium when the impact of the undesirable facility is estimated. This is why it would be preferable to use data on house sales over a sufficiently long period of time. Second, there is an inherent problem in statistically identifying the willingness to pay to avoid a disamenity. The effects of sorting in property markets play a strong role in residential location decisions. Those people who are most willing to accept a disamenity, or who have limited housing options because of income or discrimination, locate adjacent to a disamenity. As a consequence, property value differentials will underestimate the disamenity effect for the general population. Third, to the extent that the adverse activity may be locally job enhancing, adjacent house values could be elevated because of the effect of a reduction of transportation costs. Despite these limitations, which are important to bear in mind when interpreting results from hedonic pricing models, the model is very suitable to identify the scope of negative externalities generated by industrial sites as it can reveal the effect of distance to industrial sites on residential property values.

THE DUTCH CONTEXT

As in many Western countries, post-war spatial planning in the Netherlands has been dominated by mono-functional approaches. This has resulted in core spatial functions, such as housing, industry, farming, or shopping, being allocated to rather large-scale areas, often separated by 'buffers of open space'. However, several studies and the proliferation of 'mixed land-use' approaches have revealed the limitations of mono-functional land use (LAGENDIJK, 2001; VREEKER *et al.*, 2004). Whereas concepts of mixed land use aim to reduce urban sprawl and to promote spatial and environmental quality, the mono-functional approach presents a rather space-consuming form of land use which also tends to be inferior in terms of spatial quality. This notion is to a great extent reflected by the Dutch case of the provision of industrial sites, which is characterized by an abundant availability of industrial land and an associated decline of spatial quality (GORDIJN *et al.*, 2007).

In the Netherlands, local authorities are the main suppliers of building land, whether for housing or for industry. On account of their statutory planning and land policy powers, they can plan and develop industrial sites³ or facilitate enterprise zones. Therefore, the role of private agents in the supply of industrial land has always been limited; approximately 74% of the total area of industrial land is supplied by local authorities (SEGEREN *et al.*, 2005). Local authorities consider the provision of industrial sites as a key instrument of their economic policy. In accordance with their task and responsibility as a provider of industrial land, local authorities ensure that there is always a minimum amount of industrial land available for immediate sale to interested companies. Over the last decade, this approach has resulted in a yearly average disposal of 1038 hectares of industrial sites. The stock of industrial sites in the Netherlands increased from 3203 formal industrial sites in 1995 to 3605 sites in 2006. In terms of land area, this represents an increase from 78 886 to 94 560 hectares (ARCADIS AND STEC GROEP, 2007). It implies a rise of industrial land area from 1.3% to 2.7% as share of the total area of the Netherlands. Given the growth rate of land designated for housing (8.0% in the period 1993–2000), it can be inferred that the area of industrial land has risen substantially by 12.9% in the same period (GORDIJN *et al.*, 2007).

An important side-effect of the ample provision of industrial land, besides a shrinking quantity of open space, is the degradation of environment and landscape. This refers not only to the obstructing consequences of the disposal of new industrial land, but also to its contribution to the process of the ageing of existing industrial sites. According to the Dutch Industrial Sites Database (ARCADIS AND STEC GROEP, 2007), 29% of the total number of industrial sites (1052 sites) were considered as 'outdated' in 2006. These sites have substantial

vacancies in the building stock and poorly maintained public spaces. Attracted by the favourable assets of recently serviced land, well-performing companies decide to move to newly developed industrial sites. As a result, this outflow of well-performing firms generates unused industrial premises and substitution by marginal firms, which creates a downward spiral of attractiveness of older industrial sites concerned (LOUW and BONTEKONING, 2007).

In conclusion, the 'buffers' of open space are under pressure in the Netherlands. This involves a gradual diminishing of the distance of housing and other functions from industrial sites. Accordingly, the present policy of mono-functional planning, and the interplay between distance and perceived negative externalities, provides one with relevant background with regard to the impact of negative externalities originating from industrial sites, to which the remainder of this paper now turns.

DATA SET AND RESEARCH SET-UP

The data used originate from two sources: industrial site data were collected from the Dutch Industrial Sites Database (IBIS); and property data from the Dutch Association of Real Estate Agents (NVM). The selected data refer to the Randstad region⁴ and to the Province of North-Brabant in the Netherlands in the year 2005. The data collected on industrial sites and houses are all geo-referenced, which enables one to link these sets by using geographical information system (GIS) (Fig. 1).

Since the Randstad region and the Province of North-Brabant are jointly responsible for generating 51% of the total Dutch gross domestic product, these regions are considered as the economic core-regions of the Netherlands. Respectively, 41% and 15% of the Dutch population reside in the Randstad region and North-Brabant (STATISTICS NETHERLANDS, 2008). The regions studied contain a considerable amount of the national stock of industrial sites. A 500-metre buffer zone was added to the initial study area to incorporate possible effects generated by industrial sites located just outside the examined region. Hence, a sample was obtained containing information on 1201 industrial sites,⁵ acquired from the IBIS database. These sites cover 26 703 hectares of industrial land. Fig. 1 shows the spatial distribution of the industrial sites in the sample.

The IBIS database provides an inventory of formal industrial sites⁶ containing information on numerous characteristics of the industrial sites concerned, of which the variables 'location' and 'type of industrial site' are the most relevant for the purposes of this paper. Regarding the variable 'type of site', the IBIS data set distinguishes five categories of industrial sites: 'heavy industry', 'sea harbour', 'miscellaneous', 'high-tech', and 'transport'. This typology of industrial sites

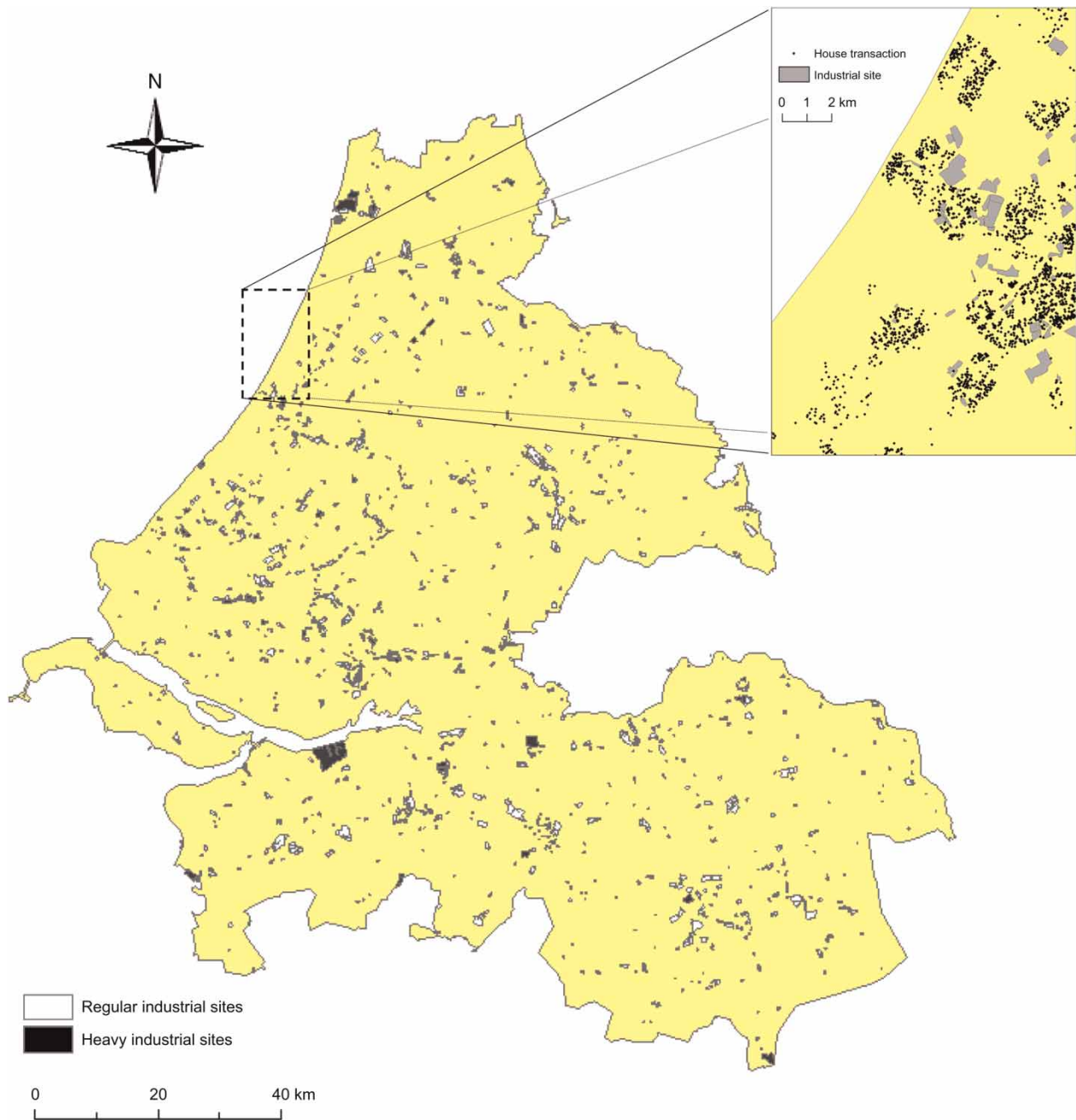


Fig. 1. Distribution of industrial sites in the Randstad and North-Brabant, the Netherlands, 2005
Source: Dutch Industrial Sites Database (IBIS)

is associated with the nature of an industrial site;⁷ it proxies the quality of the industrial sites concerned (ARCADIS AND STEC GROEP, 2007). However, the typology has a serious drawback in terms of its ability to distinguish between types of sites. In 2006, 60% of the total area of industrial land in the Netherlands (in hectares) was classified as 'miscellaneous'. The categories 'heavy industry', 'sea harbour', 'high-tech', and 'transport' represent, respectively, 10%, 18%, 4%, and 4% of the area. The remaining 4% of industrial land has been categorized as 'unknown' (ARCADIS AND STEC GROEP, 2007). This drawback is dealt with

herein by categorizing industrial sites in two classes which proxy the nature of an industrial site. 'Heavy industrial sites' are those which were originally classified as heavy industry, sea harbour, and transport sites, as these types of sites are assumed to generate substantial nuisance in terms of noise, traffic, congestion, and pollution. The category 'regular sites' comprises miscellaneous and high-technology sites. These sites are expected to create less nuisance than 'heavy sites'. In the sample, sixty-one sites are categorized as 'heavy' and 1140 sites as 'regular', covering 728 and 25 975 hectares of industrial land, respectively.

The data regarding residential property values include information on all houses sold by NVM real-estate agents⁸ in the Randstad and North-Brabant in 2005. All observations referring to a house with a volume of less than 100 m³, a floor area of less than 40 m² or a transaction price exceeding €1 million were removed. Furthermore, the upper and lower 0.5% of the transaction values of the remaining observations were excluded (for a similar approach, see ROUWENDAL and VAN DER STRAATEN, 2008). This leaves a sample containing information on 70 684 dwellings within the defined area.

Furthermore, additional geographical information on important control variables, such as the ethnic composition and population density of the neighbourhood, the location of highway exits and railway stations, and distance to jobs, was acquired from Statistics Netherlands (CBS), the National Road Database (NWB), the Dutch Railways (NS), and the Netherlands Institute for Spatial Research (RPB)/Land Use Scanner, respectively.⁹

Building on the hedonic valuation methodology, and allowing for its limitations, as described in the literature review, it was assumed that residential property values are a function of structural, neighbourhood, and industrial site variables.¹⁰ The structural variables are the physical characteristics or attributes of the residential property, and include the numerical variables 'floor area' and 'volume'. Categorical variables indicate the presence of central heating, garage and garden, the period of construction, and the type of house. The latter incorporates four basic architectural house styles: detached, semi-detached, terraced house, and apartment.

The neighbourhood variables cover the characteristics of the area in which the property is located, such as socio-economic factors, status of the area, ease of accessibility, and labour market characteristics. The ethnic composition (the fraction of ethnic minorities) and the population density of the four-digit postcode area in which the dwelling is located are included. Additionally, a regional dummy is included to indicate the region (Randstad or North-Brabant) in which the dwelling of interest is located. The ease of accessibility is controlled for in two ways. First, the ease of accessibility by road, operationalized by the road distance (metres) from each property to the nearest highway exit, is employed. Second, the ease of accessibility by railway, operationalized by the straight-line distance (metres) from each property to the nearest railway station, is employed. Allowing for the positive effects associated with the provision of local employment by the industrial site concerned, which may elevate adjacent house values, the minimum distance (circle radius in metres) within which a total of 100 000 jobs can be reached is included. This measure is a proxy for job opportunities in the vicinity of the house.

Industrial site variables refer to the perceived impact of the industrial sites that are present. This variable

encompasses the characteristics of the industrial sites which are located in the vicinity of the properties concerned. The location of an industrial site, vis-à-vis residential properties, is specified by the distance from the approximate centre of a residential property to the nearest industrial site. In this respect, the straight-line distances (metres) from each residential property to the closest point on the boundary of the industrial site is included. A dummy variable is included to indicate the category (heavy or regular) to which this nearest industrial site belongs. Furthermore, it is assumed that the size of an industrial site matters in explaining its impact on property values. Thus, the gross area (hectares)¹¹ of the industrial sites concerned are also controlled. Finally, since the data set also contains information about the date of house transactions, monthly dummies are included to capture the effects of seasonality of the housing market. Appendix A reports the variable names, their sources, definitions, and some descriptive statistics.

THE ECONOMETRIC MODEL

A formal way of describing the hedonic price function is as follows:

$$P_j = f(S_1, \dots, S_K; N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N) \quad (1)$$

where houses are identified by the subscript j ; P_j is house transaction price; and f relates the transaction price to structural (S) and neighbourhood (N) characteristics of the property, and the characteristics of the industrial sites (I) concerned. Since the effect of distance to industrial sites on property transaction prices is the variable of key interest (D), this variable is distinguished explicitly. It assumes a housing market in equilibrium, meaning that all individuals have made their utility-maximizing choices, given the prices of alternative housing locations. For individual i living in house j , the utility is given by (ROSEN, 1974):

$$u_i = u(x; S_1, \dots, S_K; N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N) \quad (2)$$

which is assumed to be strictly concave. The variable x is all other goods consumed. The price of x is set equal to 1 and the income of individual i , y_i , is measured in terms of units of x . This gives the following budget constraint:

$$y_i = P_j(S_1, \dots, S_K; N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N) + x \quad (3)$$

The maximization of utility, subject to the budget constraint, requires choosing x and $(S_1, \dots, S_K;$

$N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N$) to satisfy the budget and the first-order conditions. Therefore, partial differentiation with respect to, for example, an industrial site attribute M gives the marginal implicit price for that attribute $\partial P_j / \partial I_M$.

Economic theory provides little guidance regarding the choice of functional form for the hedonic price function (DEATON and HOEHN, 2004; NEUPANE and GUSTAVSON, 2008). The double natural log specification is widely employed for model estimation (FREEMAN, 1993), largely motivated by the fact that it allows for a simple interpretation of estimated coefficients as elasticities. However, in order to describe the pattern of distance decay, the effect of distance on house prices is measured by using distance dummies, that is, a less restrictive functional form, instead of employing the natural log of distance. Distance categories with a 250-metre range are used to enable a detailed examination of the effect to be made (DEBREZION *et al.*, 2006). Endogenous determination of the cut-off distance by running models with different cut-off distances results in a distance of 2250 metres to the nearest industrial site, beyond which house prices are no longer significantly affected by negative externalities generated by the industrial sites concerned.¹² As a consequence, the piecewise specification of distance renders nine categories up to 2250 metres. In the empirical application, the transaction price of a house j is modelled as follows:

$$\begin{aligned} \ln P_j = & \alpha + \sum_{k=1}^{15} \beta_k S_{j,k} + \sum_{l=1}^6 \gamma_l N_{j,l} \\ & + \sum_{m=1}^2 \delta_m I_{j,m} + \sum_{n=1}^9 \zeta_n D_dum_{j,n} + \varepsilon_j \end{aligned} \quad (4)$$

where all variables are defined as in equation (1). The α is a constant; and β , γ , δ , and ζ are coefficients to be estimated. The variables of structural, neighbourhood, industrial site characteristics, and the distance-to-site variable for property j are indexed by k , l , m , and n , respectively. In accordance with most of the previous literature, equation (4) is estimated by ordinary least squares (OLS). White's heteroskedastic consistent covariance matrix is used to correct the estimated errors for unknown forms of heteroskedasticity.

In the model in its simple and basic form, it is assumed that house prices rise with increasing distance to the nearest industrial site. More specifically, the sign and the magnitude of estimated coefficients of the separate distance dummies are, respectively, expected to be negative and decreasing at a decreasing rate as distance between the site and the property increases (that is, the coefficients under consideration express the price differentials between the distance category concerned and the reference group).¹³ Furthermore, *ceteris paribus*, an increase in house prices

is hypothesized to result from increases in floor area and housing volume. Increases in the age of the dwelling are hypothesized to cause a decline in house values. The price effect associated with the style of housing (that is, detached, semi-detached, terraced, or apartment) is uncertain, given that the model controls for floor area and volume. Specific assets of a house, such as the presence of central heating, garage and garden, are expected to have a positive price effect. Neighbourhood measures associated with status, such as ethnic composition and population density, are expected to influence house prices negatively, as has been shown by, amongst others, ROUWENDAL and VAN DER STRAATEN (2008). Considering the distance to jobs, a negative effect on house prices is hypothesized. The increased remoteness of households to areas of employment increases the costs of commuting. The associated expenditures will be capitalized into property values. Following DEBREZION *et al.* (2006), it is supposed that the effect of increasing distance to highway exits and railway stations on house prices is negative. Increased proximity causes positive effects in terms of accessibility, which are assumed to exceed the negative effects, such as inherent traffic nuisance. Since the Randstad is the economic core region of the Netherlands, dwellings located in this region are hypothesized to sell at a higher price than dwellings in North-Brabant. The remainder of the variables that are associated with the perceived impact proceeding from present industrial sites on house prices, for example, the size of the industrial site, and heavy sites compared with regular sites, are hypothesized to affect house prices negatively.

EMPIRICAL RESULTS

Basic results

The basic estimation results are shown in Table 1. The majority of the results are highly statistically significant (at the 1% significance level) and consistent with our hypotheses,¹⁴ including those for the distance-to-site dummies. Looking at the industrial site characteristics size and type of site, it can be seen that the corresponding estimated parameters have a negative and positive sign, respectively. On the one hand, this confirms the hypothesis that the larger an industrial site, the more inconvenience it generates. On the other hand, the effect of heavy sites on their immediate vicinity has significantly less impact than that of regular sites, which is remarkable since the heavy-industry sites are defined as industrial sites on which it is intended to establish highly undesirable effects in terms of environmental nuisance. A possible explanation for this unexpected finding is the relatively small occurrence of sites denoted as 'heavy' in the data set. It might also stem from an omitted variable bias (for example, lot sizes close to heavy sites being relatively large).

Considering distance, it is found, consistent with expectations, that increased distance from industrial sites

Table 1. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005 using a piecewise specification of distance

Variable	Coefficient	t-statistic
Constant	9.649***	(260.4)
Structural characteristics (S_k)		
\ln Floor area (m^2)	0.391***	(29.1)
\ln Volume (m^3)	0.407***	(29.4)
Detached	0.275***	(46.0)
Semi-detached	0.128***	(27.4)
Terraced	-0.022***	(-7.0)
Year of construction (before 1906)	-0.008*	(-1.7)
Year of construction (1906–1930)	-0.086***	(-24.2)
Year of construction (1931–1944)	-0.126***	(-32.1)
Year of construction (1945–1959)	-0.157***	(-42.9)
Year of construction (1960–1970)	-0.175***	(-71.6)
Year of construction (1971–1980)	-0.155***	(-65.8)
Year of construction (1981–1990)	-0.099***	(-41.7)
Central heating	0.081***	(21.9)
Garage	0.094***	(36.0)
Garden	-0.000	(-0.0)
Neighbourhood characteristics (N_l)		
Ethnic minorities (fraction of the population)	-0.644***	(65.3)
\ln Population density (inhabitants per km^2)	-0.021***	(-16.2)
\ln Distance to 100 000 jobs (metres)	-0.096***	(-51.4)
\ln Distance to highway exit (metres)	-0.019***	(-12.7)
\ln Distance to railway station (metres)	-0.012***	(-13.0)
North-Brabant regional dummy	-0.137***	(-72.9)
Industrial site characteristics (I_m)		
\ln Gross area of nearest industrial site	-0.012***	(-19.1)
Heavy industrial site dummy	0.117***	(30.6)
Distance (D_n)		
0–250	-0.149***	(-21.4)
250–500	-0.139***	(-20.1)
500–750	-0.122***	(-17.5)
750–1000	-0.109***	(-15.5)
1000–1250	-0.103***	(-14.2)
1250–1500	-0.087***	(-11.5)
1500–1750	-0.051***	(-6.3)
1750–2000	-0.034***	(-3.9)
2000–2250	-0.004	(-0.4)
Adjusted R^2	0.774	
Number of observations	70 684	

Note: The month of sale has been controlled for. Estimated coefficients are not reported, but are available from the authors on request. White t -values are given in parentheses; ***significant at the 1% level; and *significant at the 10% level.

increases house prices. *Ceteris paribus*, houses located within 250 metres of an industrial site are predicted to sell at 14.9% less than houses located beyond a distance of 2250 metres from such a site (the reference group). The estimated relationship, employing the linear piecewise distance specification and a given set of characteristics, is shown in Fig. 2. It illustrates the value of the representative property¹⁵ as a function of the distance-to-site dummy (keeping all other variables constant).

In Fig. 2, the depicted pattern suggests a logistic shape, representing the (partial) relationship between the distance to the closest industrial site and house prices. One therefore proceeds by replacing the

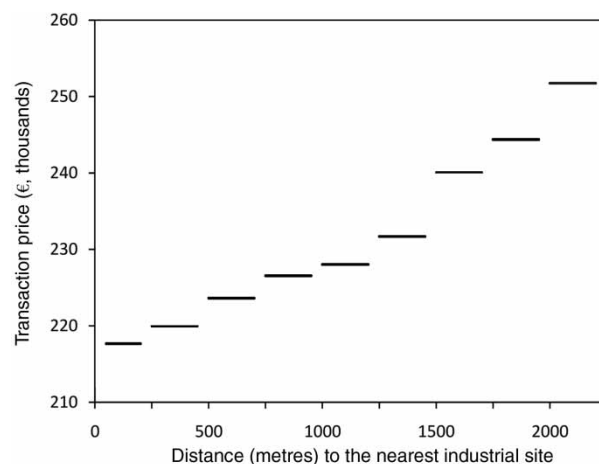


Fig. 2. Transaction price gradient function for a representative property (piecewise specification)

piecewise specification of distance with a logistic functional form of distance. More specifically, the following model is estimated using non-linear squares:

$$\ln P_j = \alpha + \sum_{k=1}^{15} \beta_k S_{j,k} + \sum_{l=1}^6 \gamma_l N_{j,l} + \sum_{m=1}^2 \delta_m I_{j,m} + \eta_1 \frac{e^{\eta_2 + \eta_3 \ln(D_j)}}{1 + e^{\eta_2 + \eta_3 \ln(D_j)}} + \varepsilon_j \quad (5)$$

where all variables are defined as in equation (1). Because of the transformation into the logistic specification for distance, three parameters, η_1 , η_2 , and η_3 , are estimated which together characterize the partial relationship between distance and house price. More specifically, the maximum variation of house prices as a function of distance to the nearest industrial site is captured by parameter η_1 . Furthermore, the relationship is upward sloping if $\eta_1 \cdot \eta_3 > 0$, and the point of inflection (namely, the distance at which the curve is steepest, and thus beyond which the effect of the presence of the industrial site gradually diminishes) can be derived as:

$$D_j^* = \left(\frac{\eta_3 - 1}{e^{\eta_2}(1 + \eta_3)} \right)^{1/\eta_3} \quad (6)$$

The point of inflection thus decreases with increasing values of η_3 . See Appendix B for technical details.

The results of the estimation are presented in Table 2. Since the other estimated coefficients remain generally unchanged, only the outcomes referring to the effect of distance from an industrial site on house prices are reported.

With reference to the goodness of fit and the parsimony of the preceding models, an examination of corresponding criteria does not point to one of the models being clearly preferred over the other.¹⁶

Table 2. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005 using a logistic specification of distance

Variable	Coefficient	t-statistic
Constant	9.506***	(261.7)
Distance (D_j)		
η_1	0.169***	(8.8)
η_2	-18.445***	(-10.7)
η_3	2.516***	(9.6)
Adjusted R^2	0.774	
Number of observations	70 684	

Note: Only the estimation results referring to the effect of distance are reported (full estimation results are available from the authors on request); White t -values are given in parentheses; ***significant at the 1% level.

However, given the advantages with respect to interpretation and presentation, it was decided to use the more parsimonious model to characterize the relationship between distance to industrial site and house prices. On that account, a detailed look at the employed logistic functional form of house prices as a function of the minimum distance of a house to its nearest industrial site gives more precise information about the nature of the distance decay of the negative externalities which are generated by the industrial sites. The partial relationship between house prices and distance to the nearest industrial site can be represented as:

$$P(D_j) = 0.169 \frac{e^{-18.445 + 2.516 \ln(D_j)}}{1 + e^{-18.445 + 2.516 \ln(D_j)}} = \frac{0.169 e^{-18.445} D_j^{2.516}}{1 + e^{-18.445} D_j^{2.516}} \quad (7)$$

Moreover, from equation (6), the point of inflection (D_j^*) can be derived. It appears that up to a distance

of 1093 metres, house prices are increasing at an increasing rate, whereas house prices are increasing at a decreasing rate beyond this distance. This relationship is depicted in Fig. 3. It illustrates the value of the representative property given a change in the distance-to-site variable, holding the other variables constant.

The revealed shape of the curve in Fig. 3 is in accordance with expectations. It illustrates that the impact of negative externalities generated by industrial sites is largely localized. Increasing distance leads to a gradually diminishing increase of house prices.

A more detailed look at industrial site size

In view of the estimation results of equation (5), it is inferred that the nature of the distance decay of negative externalities generated by industrial sites is largely localized. Amongst other things, it has been shown that the point of inflection is at 1093 metres. However, the potential relevance of the interplay between the effect of distance and another relevant industrial site characteristics, such as the gross area of the site, have been neglected.

The value of the estimated coefficient of the gross area of the nearest industrial site, irrespective of which model is used, equals -0.012 (statistically significant at the 1% level). This implies that an increase of 1% of the gross area of the nearest industrial site decreases house price by 0.012%. However, it is plausible to contend that the effect of the increase of site area on house prices modifies with increasing distance from the site concerned. One therefore allows for interaction effects between gross site area and distance to the nearest site. The interaction of these parameters with industrial site acreage will result in a change of the nature of the distance decay, in that it becomes conditional on site acreage. However, sequential regression model runs (non-linear squares)

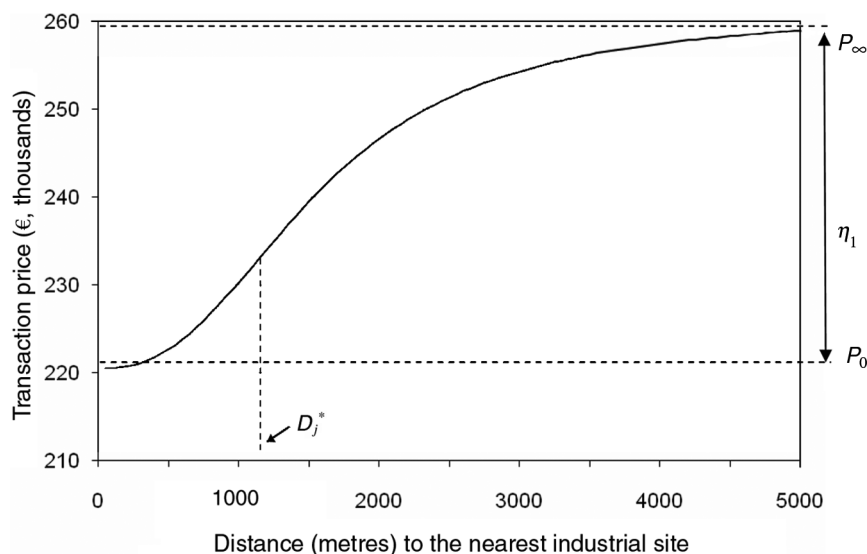


Fig. 3. Transaction price gradient function for a representative property (logistic specification)

for separate ‘site size–distance’ interaction terms, and all three site size–distance interaction terms together, only yield statistically significant estimates (at the 5% level) for the model which controls for $\eta_1 \cdot \text{Ln Gross area}$ (φ_1).¹⁷ This model is specified as follows, where all variables are defined as in equation (5):

$$\begin{aligned} \text{Ln} P_j = & \alpha + \sum_{k=1}^{15} \beta_k S_{j,k} + \sum_{l=1}^6 \gamma_l N_{j,l} + \sum_{m=1}^2 \delta_m I_{j,m} \\ & + \eta_1 \frac{e^{\eta_2 + \eta_3 \text{Ln}(D_j)}}{1 + e^{\eta_2 + \eta_3 \text{Ln}(D_j)}} \\ & + \varphi_1 (\eta_1 \cdot \text{Ln Gross area}_j) \frac{e^{\eta_2 + \eta_3 \text{Ln}(D_j)}}{1 + e^{\eta_2 + \eta_3 \text{Ln}(D_j)}} + \varepsilon \quad (8) \end{aligned}$$

The results of the estimation are presented in Table 3. Only the outcomes referring to the effects of site size, distance from an industrial site, and the corresponding interaction effect on house prices are reported.

The estimated interaction coefficient (φ_1) indicates that the effect of distance on house prices, referring to the range, rises with increasing site size. In other words, an increase of 1% gross area of the industrial site concerned elevates the accompanying distance effect by 0.008%, *ceteris paribus*. This effect is shown in Fig. 4. It depicts the price gradients of representative properties whose nearest industrial sites have a gross area of 1, 25, and 50 hectares, given a change in the distance-to-site variable. As well as observing that the overall price level of houses located near ‘small’ industrial sites exceeds the price level of ‘larger’ sites, it can also be observed that the range or variation of the house prices increases as the size of the nearest industrial site increases. Furthermore, the relationship between site size and distance to the site appears to be

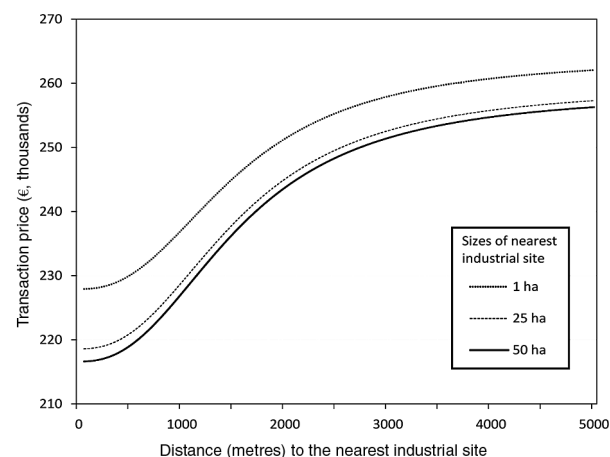


Fig. 4. Transaction price gradient functions for the sizes of various different sites

non-linear, in the sense that the effect of size change is relatively larger for ‘small’ sites than for ‘large’ sites.

Robustness analysis

The results so far show that the findings concerning the marginal effect of the presence of an industrial site on house prices, as measured by distance to site, are robust to the employed functional forms, namely the piecewise and logistic specification of distance. In accordance with the findings concerning goodness of fit and parsimony of the model, the use of the logistic functional form is preferable. In order to test the robustness of the results, the corresponding regression model was replicated by employing different subsets of the original data. Finally, municipality dummies were added to the basic model to examine whether the results are sensitive to potential unobserved local circumstances.

First, model runs were conducted for four different subsamples comprising houses which are located, respectively, within 500, 1000, 1500, and 2000 metres from the nearest industrial site. The regression estimates are strongly in line with the findings discussed above: they confirm that there is a lack of variation in house prices within a short distance from an industrial site, and, conversely, that expanding the sample sizes leads to a rise of house price variation across distance as, amongst others, represented by an increasing parameter η_1 .¹⁸

Second, we examined the sensitivity of the empirical results to regional specifications by dividing the transaction data into two subsamples, namely the Randstad and the Province of North-Brabant, respectively.¹⁹ The model run for the Randstad sample yields coefficients which are fully consistent with the general findings, regarding sign as well as the statistical significance of the estimated effects. However, the impact of the presence of an industrial site on house prices appears to be more pronounced in the Randstad region than in the entire area of examination, in the sense that house prices are increasing at a faster rate as the distance

Table 3. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005 using a logistic specification of distance: the interaction effect between distance and industrial site size

Variable	Coefficient	t-statistic
Constant	9.511***	(261.7)
Size of nearest industrial site		
Ln Gross area	−0.013***	(15.6)
Distance		
η_1	0.147***	(7.5)
η_2	−17.700***	(−10.6)
η_3	2.419***	(9.4)
Interaction distance and size		
φ_1	0.008**	(2.3)
Adjusted R ²	0.774	
Number of observations	70 684	

Note: Only the estimation results referring to the (interaction) effects of distance are reported (full estimation results are available from the authors on request); White t-values are given in parentheses; ***significant at the 1% level; and **significant at the 5% level.

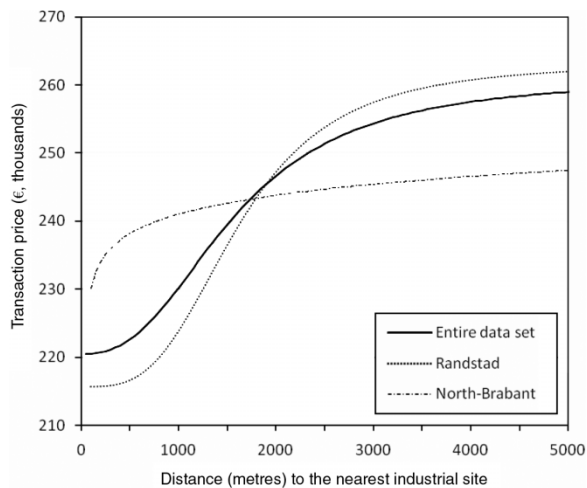


Fig. 5. Transaction price gradient functions for different regional samples

to the nearest industrial site increases. For the sake of comprehensibility, these outcomes are shown in Fig. 5. Conversely, the results for North-Brabant with regard to distance yield statistically insignificant outcomes. Displaying the corresponding transaction price gradient reveals a relationship between distance and house price which exhibits a logarithmic form.²⁰ In North-Brabant, the effect of the presence of an industrial site on house prices is, apparently, manifested within a relatively short distance of the site concerned. To obtain more insight into this regional anomaly, additional model runs were conducted for the Province of North-Brabant and the Randstad separately, explicitly accounting for the nature of industrial sites in terms of type and size.²¹ The outcomes turned out to be consistent with the aforementioned findings. In North-Brabant, beyond a distance of approximately 750 metres, there is no discernible impact of distance to the closest site on house prices, irrespective of the type and size of the industrial site. Concerning the Randstad, the revealed partial relationship between distance to the industrial site and house prices features a logistic shape. Given that the industrial site characteristics of the investigated regions have been controlled, the functioning of regional housing markets thus seems to differ considerably. Likewise, replicating the preceding regressions using the piecewise distance specification instead of the logistic distance specification yields consistent results, indicating that the employed model is sensitive to geographical considerations.²²

Finally, estimating the basic model with the inclusion of 219 municipality dummies, each corresponding to the municipality in which the dwelling concerned is located (taking the municipality of Amsterdam as a reference group), yields outcomes which are qualitatively as well as quantitatively comparable with those obtained with the basic logistic specification (Table 4). Considering the estimated partial relationship between the distance to industrial site and house prices, the

Table 4. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005, including municipality dummies

Variable	Coefficient	t-statistic
Constant	9.510***	(232.6)
Distance (D_i)		
η_1	0.186***	(2.7)
η_2	-13.006***	(-8.0)
η_3	1.653***	(5.8)
Adjusted R^2	0.839	
Number of observations	70 684	

Note: Only the estimation results referring to the effect of distance are reported (full estimation results are available from the authors on request); White t-values are given in parentheses; ***significant at the 1% level.

parameter η_1 , which captures the maximum variation of house prices as a function of distance to the nearest industrial site, increases slightly from 0.169 to 0.186. Furthermore, by using equation (7), the point of inflection is at 1133 metres (instead of at 1093 metres). The remainder of the estimated coefficients are also consistent with the basic model estimates. Hence, it can be inferred that the revealed effect of distance to site on house prices is robust, in the sense that its nature is hardly affected by potential unobserved heterogeneity, stemming from specific local circumstances.

CONCLUSION

The main aim of this paper was to study the impact of the presence of industrial sites on their immediate vicinity. Applying a hedonic pricing model, the negative externalities generated by activities located on industrial sites in the Randstad region and the Province of North-Brabant (both in the Netherlands) in the year 2005 were valued. The effect of these negative externalities is proxied by estimation of the distance-decay of house prices in the vicinity of industrial sites. In accordance with previous hedonic pricing studies, the results clearly show that the presence of an industrial site has a statistically significant negative effect on the value of residential properties: house prices rise with increasing distance to the nearest industrial site. However, in contrast to previous hedonic pricing studies that are known to the authors, the present papers employs a logistic functional form to reveal the nature of the effect of distance-to-site on house prices. This leads to a relationship between distance and residential property prices which is best described as 'dichotomous': relatively close to a site, negative externalities have a strong negative effect on house prices, which convexly decreases up to a certain distance. Beyond this point, in the present case 1093 metres, the negative effect on house prices concavely decreases till it fades out with increasing distance. Furthermore, it is found that the effect of site

size intervenes with the effect of distance on house prices, in the sense that this interactive effect affects the maximum variation of the distance effect: the larger the site, the larger the range of houses that are affected by the presence of the industrial site concerned.

These outcomes demonstrate that the impact of negative externalities is largely localized, implying that the perception of the spatial quality of the neighbourhood is affected by the presence of an industrial site, and to a certain extent by the size of an industrial site. In addition, this study may provide spatial planners with more insight into setting zoning guidelines in order to decrease potential inconvenience resulting from the presence of an industrial site. One has to be careful, however, in deriving inferences with regard to the latter, as this study only employs the revealed preferences of house buyers in the vicinity. In view of this, it should be taken into account that this approach is sensitive to sorting of individuals driven by variation in the willingness to accept a disamenity. This may be manifested by an underestimation of the distance-to-site effect within a short distance of an industrial site. The results, furthermore, neglect the preferences of other stakeholders, for instance employees of the firms located on the sites or visitors to these firms, who may

attach different values to the impact of industrial sites. Another possible shortcoming is the variation across regions. As substantially different parameters regarding the effects of distance on house price for the Randstad and North-Brabant subsets were obtained, it reduces the general applicability of the method. This regional sensitivity may be of special importance for policy-makers.

In conclusion, the findings of this paper provide insight into the extent of negative externalities involved with the location of certain industrial activities on a specific site. The observed impacts address the notion of the spatial quality of an industrial site. Despite some caveats, they provide useful information that can help with prioritizing and assessing spatial planning approaches.

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APPENDIX A

Table A1. Definitions, sources, and descriptive statistics for the variables used in the empirical analysis

Variable	Description	Source	Mean	SD
<i>Price</i>	Transaction price, 2005 (€)	NVM	254 522.33	141 377.12
Structural characteristics				
<i>Floor area</i>	Size of the living area of the house (m ²)	NVM	120.24	49.51
<i>Volume</i>	Volume of the house (m ³)	NVM	353.28	220.34
<i>Detached</i>	Dummy variable: equals 1 if the house is detached	NVM	0.08	0.27
<i>Semi-detached</i>	Dummy variable: equals 1 if the house is semi-detached	NVM	0.10	0.31
<i>Terraced</i>	Dummy variable: equals 1 if the house is a terraced house	NVM	0.46	0.50
<i>Apartment</i>	Dummy variable: equals 1 if the house is an apartment	NVM	0.36	0.48
<i>Before 1906</i>	Dummy variable: equals 1 if the house was built before 1906	NVM	0.06	0.24
<i>1906–1930</i>	Dummy variable: equals 1 if the house was built in the period 1906–1930	NVM	0.14	0.34
<i>1931–1944</i>	Dummy variable: equals 1 if the house was built in the period 1931–1944	NVM	0.09	0.28
<i>1945–1959</i>	Dummy variable: equals 1 if the house was built in the period 1945–1959	NVM	0.08	0.26
<i>1960–1970</i>	Dummy variable: equals 1 if the house was built in the period 1960–1970	NVM	0.15	0.36
<i>1971–1980</i>	Dummy variable: equals 1 if the house was built in the period 1971–1980	NVM	0.15	0.36
<i>1981–1990</i>	Dummy variable: equals 1 if the house was built in the period 1981–1990	NVM	0.14	0.35
<i>After 1990</i>	Dummy variable: equals 1 if the house was built after 1990	NVM	0.20	0.40
<i>Central heating</i>	Dummy variable: equals 1 if the house has central heating	NVM	0.92	0.27
<i>Garage</i>	Dummy variable: equals 1 if the house has a garage	NVM	0.20	0.40
<i>Garden</i>	Dummy variable: equals 1 if the house has a garden	NVM	0.56	0.50
Neighbourhood characteristics				
<i>Ethnic minorities</i>	Fraction of inhabitants of non-Western origin in the postcode area (four digit) of the house	CBS	0.12	0.11
<i>Population density</i>	Number of inhabitants per km ² in the postcode area (four digit) of the house	CBS	5361.07	3935.07
<i>Distance to highway exit</i>	Distance, by road, from the house to the nearest highway exit (metres)	NWB	3993.81	2548.18
<i>Distance to railway station</i>	Straight-line distance from the house to the nearest railway station (metres)	NS	3142.00	3279.79
<i>Job accessibility</i>	Minimum distance (circle radius) within which a total of 100 000 jobs can be reached (metres)	RPB/LS	8492.26	4511.54

(Continued)

Table A1. Continued.

Variable	Description	Source	Mean	SD
North-Brabant	Dummy variable: equals 1 if the house is located in the Province of North-Brabant	NVM	0.27	0.44
Industrial site characteristics				
Distance to industrial site	Straight-line distance from the house to the boundary of the nearest industrial site (metres)	IBIS	784.39	606.72
Gross area	Gross area of the nearest industrial site (hectares)	IBIS	34.02	58.45
Regular industrial site	Dummy variable: equals 1 if the nearest industrial site concerns a miscellaneous or high-technology site	IBIS	0.93	0.27
Heavy industrial site	Dummy variable: equals 1 if the nearest industrial site concerns a heavy industry site, sea harbour or transport site	IBIS	0.07	0.27

Notes: CBS, Statistics Netherlands; IBIS, Dutch Industrial Sites Database; LS, Land Use Scanner; NS, Dutch Railways; NVM, Dutch Association of Real Estate Agents; NWB, National Road Database; RPB, Netherlands Institute for Spatial Research; SD, standard deviation.

The sample size was 70 864 observations.

APPENDIX B

This Appendix derives the characteristics of the logistic specification for the partial relationship between house prices and distance to the closest industrial sit. It starts from the basic function:

$$F(D_j) = \eta_1 \frac{e^{\eta_2 + \eta_3 \ln D_j}}{1 + e^{\eta_2 + \eta_3 \ln D_j}} = \frac{\eta_1 e^{\eta_2} D_j^{\eta_3}}{1 + e^{\eta_2} D_j^{\eta_3}} \quad (B1)$$

The first-order derivative of this function (F) with respect to distance (D) equals:

$$F'(D_j) = \frac{\eta_1 \eta_3 e^{\eta_2} D_j^{\eta_3 - 1}}{(1 + e^{\eta_2} D_j^{\eta_3})^2}$$

therefore:

$$F'(D_j) > 0 \quad \text{if } \eta_1 \cdot \eta_3 > 0 \quad (B2)$$

The second-order derivative equals:

$$F''(D_j) = \frac{(1 + e^{\eta_2} D_j^{\eta_3}) D_j^{\eta_3 - 1} e^{\eta_2} \eta_3 \eta_1}{(1 + e^{\eta_2} D_j^{\eta_3})^4}$$

therefore:

$$F''(D_j) = 0 \quad \text{if } D_j^* = \left(\frac{\eta_3 - 1}{e^{\eta_2} (1 + \eta_3)} \right)^{1/\eta_3} \quad (B3)$$

For $0 < D_j < D_j^*$, $F(D_j)$ is an increasing convex function of D_j , if $\eta_3 > 0$. For $D_j^* < D_j < \infty$, $F(D_j)$ is an increasing concave function of D_j , if $\eta_3 > 0$.

NOTES

- Five categories of industrial sites have been defined: 'heavy industry', 'sea harbour', 'miscellaneous', 'high-tech', and 'transport'. This typology of industrial sites, as defined by IBIS, is associated with the nature of the industrial site concerned.

- See, for example, ZEISS (1999), who analyses the results of sixty-nine studies dealing with the negative effects of industrial facilities on their direct vicinity.
- In general, an industrial site can be considered as a collective location for the establishment of firms (BAK, 1985). Sites designated exclusively for offices are not covered by this definition.
- The Randstad region comprises the following areas: the Province of North-Holland (excluding Alkmaar and the surrounding area and the northern part of North-Holland) and the Provinces of South-Holland and Utrecht. For more details about regional definitions, see RIETVELD and WAGTENDONK (2004).
- The examined area originally comprised 1718 industrial sites. Information on the 'type of industrial site' is only available for 1201 sites. Those houses closest to an industrial site but for which no information on the type of industrial site was available were eliminated from the sample.
- An industrial site is defined as 'a location which the land-use plans deem suitable for activities in the branches of commerce, manufacturing, commercial services, industry, and whose original design is larger than one hectare'.
- Heavy-industry sites are industrial sites on which it is intended to establish highly undesirable facilities in terms of environmental nuisance (for example, landfills, demolition dumps, waste sites, hazardous manufacturing facilities, etc.). Sea harbours comprise large-scale sites featuring freight facilities for maritime shipping activities. Miscellaneous sites are commonly seen as regular industrial sites that include a large variety of activities (ranging from small to medium polluting activities), on the condition that these sites may not be categorized as high-tech or transport. High-tech sites are those developed for high-tech production activities and research and development activities. Transport is characterized by a dominant presence of logistics and wholesale activities.
- NVM real-estate agents deal with approximately 70% of all property transactions in the Netherlands.
- These data sets were provided by SPINLab, VU University Amsterdam.
- Rents are controlled in the Netherlands, implying that their values are determined by a restricted system of points that highly disregards neighbourhood

characteristics. The authors, therefore, do not take into account rented housing in the analysis.

11. Gross area is defined as the total area designated as the industrial site, including the area used for infrastructure, water, green space, and other forms of public open space.
12. Details are available from the authors on request.
13. The results might be biased due to a possibly negative correlation between distance to the industrial sites and distance to, for example, public goods provided in the city centre. This problem becomes more severe if many industrial sites are located in the urban fringe. This bias is likely to be limited in the present case because (1) the sample comprises both inner-city industrial sites and fringe sites (for example, greenfield sites); and (2) the empirical analysis controls for a range of characteristics of city centres that may positively affect house prices, thus reducing the bias due to an omitted variable (namely, distance to 'goods' typically provided in city centres such as railway stations and employment).
14. Concerning the impact of the age of the dwelling on house prices, alternative models have been estimated by applying a linear and a quadratic specification for the year of the transaction. The estimated coefficients are consistent with the general findings regarding sign as well as statistical significance of the estimated effects. Details are available from the authors on request.
15. The representative property is defined as the hypothetical property for which all explanatory variables (namely, attributes of the property), except for distance to the industrial site, are set at their respective means.
16. The adjusted R^2 of both models is 0.774. The Akaike Information Criterion (AIC) for the respective models is -0.251 for the piecewise model, and -0.250 for the logistic model. The model with a lower AIC is typically preferred.
17. The estimation results of the other models that are related to the interaction between site size and distance are available from the authors on request.
18. Sampling along the spatial dimensions concerned creates data sets consisting of the following number of observations: fewer than 500, $N = 27\,711$; fewer than 1000, $N = 50\,660$; fewer than 1500, $N = 62\,485$; and fewer than 2000, $N = 67\,600$. The estimation results related to this sensitivity analysis are available from the authors on request.
19. Sampling along the regional dimensions concerned creates data sets consisting of the following number of observations: Randstad, $N = 51\,689$; and North-Brabant, $N = 18\,995$.
20. This has been confirmed by running an alternative regression (ordinary least-squares – OLS) using the natural logarithm of distance. The regression yields statistically significant estimates of the log of distance (at the 1% significance level). Estimation results are available from the authors on request.
21. The additional models comprise four basic regression runs per region for different compositions of the samples: a sample with only small sites (fewer than 35 ha), a sample with only large sites (greater than 35 ha), and samples with only heavy and non-heavy sites, respectively. The estimation results are available from the authors on request.
22. The estimation results are available from the authors on request.

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